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Desertification in mountain geosystems: a case study of the Ishmantupsay basin in the Gobduntau mountain range, Uzbekistan

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Abstract. A high rate of population growth in Central Asia is increasing human impact on nature resulting in rapid desertification, not only in lowlands, but also in mountainous areas. Overstocking of rangelands with livestock is causing severe and ongoing degradation of vegetation. According to expert estimates, productivity in mountain pastures has decreased by 40 - 60% in the last 50 - 60 years. In low and average elevation mountains, trees and shrubs are almost completely removed. Due to deterioration of vegetation cover in mountains, soil erosion has developed strongly, gravitational processes and mudflows have become frequent and many springs have begun to dry up. The purpose of our research is to show the scale of influence of human activity on mountain nature and to study desertification and other negative processes which develop in mountain systems under the influence of anthropogenic factors using the Gobduntau mountain range in Uzbekistan as a case study.

Key words: arid climate, degradation, desertification, geosystem, rangeland productivity, regression

Introduction

The high rate of human population growth in Central Asia is increasing anthropogenic impacts on nature resulting in rapid desertification, not only in lowlands, but also in mountainous areas. Excessive grazing influences vegetation in various ways. First of all, grazing causes diverse morphological and physiological changes in plants, breaks regularities in phonological phases, and also influences the structure of plant populations. As a result of frequent grazing, the size of a plant, its shape, level of foliar cover, level of vitality, number of flowers, fruits and seeds, ratio of foliar and generative branches are altered (Morozova 1972).

Research has established that changes in the sizes of root systems of plants subject to excessive grazing results in their restriction to the surface in the top soil horizon. Thus roots have decreased opportunity to extract moisture from deeper soil horizons, which is especially significant in conditions of a drought climate. The reduction of the aboveground portion of the plant as a result of cattle grazing on green parts results in reduction of root weight and exhaustion of plant nutrient stores. As a result, plants cannot complete physiological cycles and reproductive processes, fruiting and the production of viable seeds. All this results in changes of species composition of rangeland vegetation, reduced productivity and forage biomass.

Excessive grazing also leaves the soil bare and compacted. Research has shown that the greatest impact occurs in the upper 10 cm of the top soil profile. Moreover, whereas in the absence of grazing soil erosion is practically absent, it increases up to 20 tonnes per ha on grazed slopes (Kosminin 1979).

The purpose of our research is to show the scale of influence of human activity on mountain nature and to study desertification and other negative processes which develop in mountain systems under the influence of anthropogenic factors, using the Gobduntau mountain range in Uzbekistan as a case study.

Materials and Methods

Study area

The Gobduntau range extends for 40 km from east to west, with a maximal width of 14 km. Its mountains are of average elevation, the highest point in the central part being 1,728 m. From this point, the mountain range is lower in the east (864 m) and west (744 m). Due to the absence of a meteorological station it is difficult to report the precise amount of annual atmospheric precipitation within the range. Extrapolating from the data of nearby meteorological stations (Gallaaral, Bulungur), where average annual precipitation is 380 - 400 mm, it can be presumed that the high parts of the mountain range receive about 500 mm of precipitation per year. Precipitation is highest in winter (up to 30%) and spring (up to 50%). In summer months and at the beginning of autumn there is almost no rain. As a result, the basic territory of the mountain range is covered by desert and semi-desert vegetation communities. Dryland plants only develop on shady slopes of northern exposition above 1,250 - 1,300 m.

Discharge of underground water occurs in a zone at the interface between mountains and foothill plains. In this zone, there are hundreds of constantly running springs, with outflows ranging from 0.1 to 10 - 20 l/s. The population size of human settlements is directly linked to the amount of water available. There are more than 30 settlements within the Gobduntau mountain range with between 300 and 9,000 inhabitants each. All large settlements are located in the foothills of the northern slope in a zone where underground water discharges to the land surface. On the southern side, because there is a shortage of water, the number and size of settlements is 4 - 6 times less, but there are hundreds of smaller settlements of up to 100 people each throughout the mountain range. Each family has an average of four children. Due to the shortage of water, irrigation for agriculture is not advanced except for household plots of local communities using spring or underground water. The basic economic activity of the local population is therefore livestock breeding. Each household typically has 2 - 5 head of cattle and up to 20 small stock. Livestock is grazed almost the whole year round in foothills and mountain rangelands.

Methods

One of the specific features of geographical research is the mapping and drawing plans showing relief, the hydrographic network and other elements of a certain area, of both natural and anthropogenic origin. Such maps serve as the basis for drawing up various thematic maps, visualisation of geobotanical and landscape structures, selection of sites of study plots etc. For these reasons we made a plan of the eastern part of Gobduntau in the vicinity of Ishmantup settlement, with a scale of 1:10,000. This plan formed the basis for drawing up a landscape map of geosystems in Ishmantupsay basin (Fig. 1). In our understanding the terms geosystem, landscape, morphological parts of a landscape

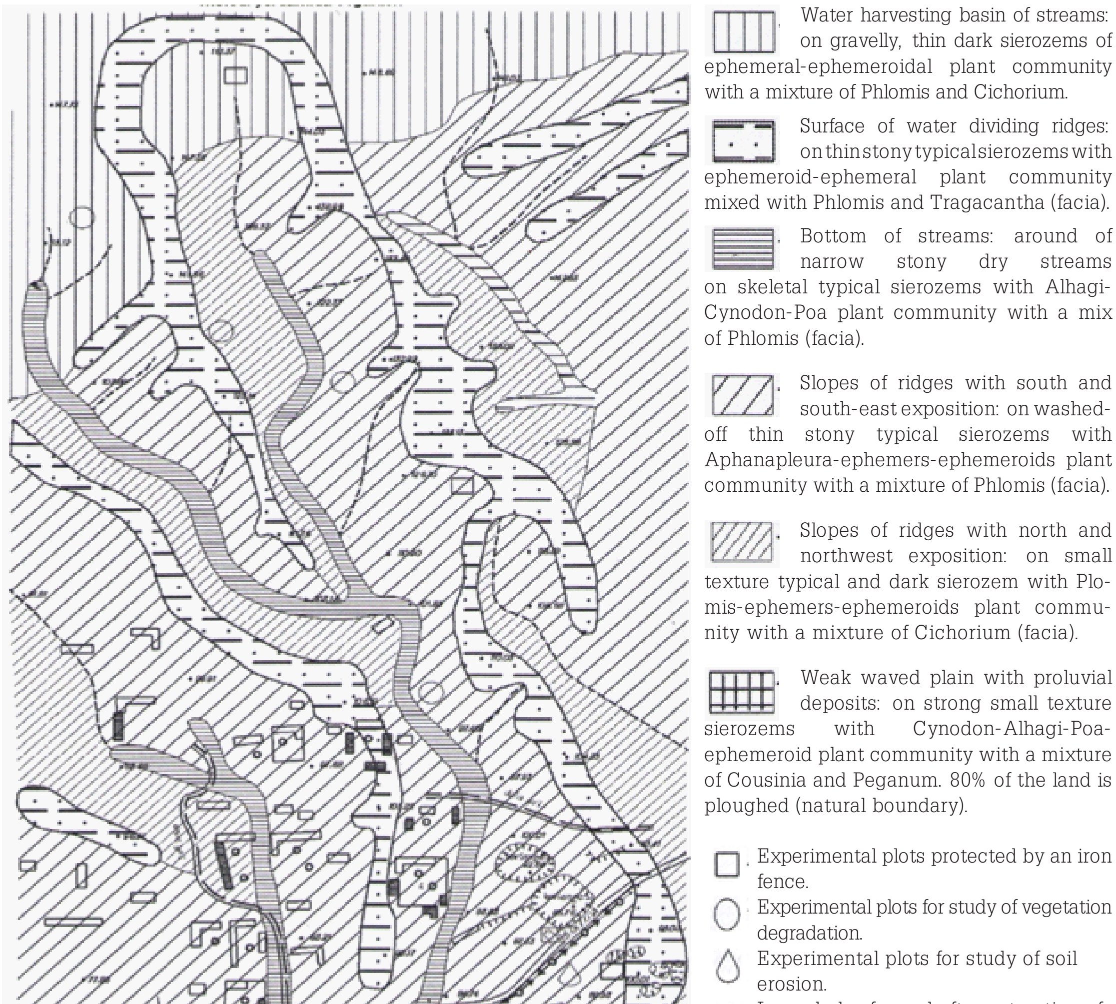

Fig. 1. Allocation of geosystems in Ishmantupsay basin in east part of Gobduntau mountain range.

(facia, natural boundary, area) are synonyms. The map shows inner-landscape morphological units - facia and natural boundary - for the selection of which the relief, elevation and genesis of superficial adjournment were taken into account.

Three basic plots for experimental works are shown on the map, located at 500 m, 300 m and 2,000 m from Ishmantup settlement. All three plots were protected by an iron fence, within which plants developed in protected conditions without intervention of livestock. The first plot 10 m long by 6 m wide (Fig.2).

Fig. 2. Site no. 1 (60m^2). Seedlings of local trees and shrubs inside the fenced area. Outside the fence there is a hole and stones prepared for sale.

It was divided into two parts. In one half, three seedlings of each of three local shrubs and trees (*Juniperus seravshanica*, *Amygdalus spinosissima*, *Ulmus pumila*) were planted in order to investigate if they could grow without irrigation in natural conditions. The second half of the fenced area was left for observation of development of annual and perennial grasses. Inside and outside the fenced area a special tool called a "tray" was established to measure the amount of soil washed from slopes. The other two fenced plots were smaller (5 m^2) and were used to make observations on the dynamics of vegetation restoration in degraded rangelands.

To estimate scales of influence of cattle grazing on the condition of vegetation cover we used a plot assessment of selected sites. For this purpose we chose four sites of 100 m^2 each (Fig. 3) at various distances from human habitation (Kultiasov 1923). At each site the following were determined: projective cover, level of bareness of slopes by trampling pathways of livestock and due to other reasons, richness of dominant plants, phytomass and the general physiological condition of plants. Description and field measurements were conducted four times per year, once in each season, with additional measuring in spring and at the end of the vegetative period. We measured to an accuracy of 1 cm the absence of vegetative cover, depth of erosion, level of vegetative cover and distribution of dominant plants. Data were entered on a plan of the site.

Data on human population and activity were compiled in order to determine the anthropogenic load on rangelands of each settlement. Whereas there are families with only one cow and a few small stock, others have 10 - 15 cattle and 100 -150 small stock. For the purposes of analysis, we used four cattle and 15 small stock as averages per family. It was therefore assumed that a settlement of 100 families would daily graze 400 head of cattle and 1,500 head of small stock.

Results and Discussion

Due to the aridity of the climate, rangeland productivity is low. Geobotanists have estimated

Fig. 3. White fences for measuring degradation of vegetation on slopes.

that one sheep requires 2 - 2.5 ha of rangeland. Many sites in the Gobduntau mountain range are presently overstocked, especially rangelands located around settlements. According to our calculations, in mountain and foothill conditions the average radius within which livestock is grazed is 5 km. Depending on the complexity of the relief, the largest loading is in sites with a radius of up to 2 - 3 km. In such sites, the present load is 10 times greater than the rangeland carrying capacity.

Unorganized collection of plants by local people plays a prominent role in deterioration of vegetation. Frequently, perennial semi-shrubs such as *Artemisia tenuisecta, Alhagi sparsifolia and Cousinia karatavica* are prepared for forage using a sharp iron tool called a *ketmen*. Roots are cut at a depth of 5 - 10 cm below the soil surface, which negatively influences restoration, frequently resulting in destruction of plants. The collection of young plants also affects their restorative ability. Under the influence of these factors, the vegetation of the Gobduntau mountain range is deteriorating year to year.

Another prominent factor leading to deterioration of vegetation cover in Gobduntau is the preparation of stones for construction work. Due to a lack of other employment opportunities, young people prepare and sell stones which are used in the foundation of all buildings. Demand is high and on mountain slopes around every settlement there are tens, sometimes hundreds, of holes of various sizes resulting from the extraction of stones (Fig. 4). Some of them reach 30 - 40 m in diameter, with a depth of up to 2.5 m. Around each hole there is a lot of gravel and small stones left after loading larger stones into a machine. For a distance of up to 2 - 4 m around larger holes the soil surface and vegetation are completely covered by gravel and for up to 5 - 6 m they are 50% covered. Each hole is a microcenter of desertification: the vegetation does not recover for decades. According to local inhabitants, small springs on mountain slopes started to dry up following stone extraction and in Ishmantup the level of underground water in wells has decreased for 1.5 - 2 metres.

The most serious impact on vegetation cover is that of cattle grazing. The negative influence of cattle on rangeland was found to increase with stocking density. The proportion of slopes which were bare (lacked vegetation) decreased with increasing distance from human habitation: 60 - 90% within 1,000 m of a settlement; 40 - 60% at 1,000 - 2,000 m; 30 - 40% at 2,000 - 3,000 m; 20 - 30% at 3,000 - 5,000 m. These values are averages and vary from year to according to weather conditions: the proportion of bare slopes decreases in rainy years and increases in drought. Livestock pathways are clearly visible on slopes (Fig. 5 and 6). Their density decreases with increasing distance from human habitation. When the areas of these pathways are combined they make up to 60% of total rangeland, especially close to settlements.

Fig. 4. Holes left after preparation of stones. In the foreground *Phlomis thapsoides*, in the background arable land.

Fig. 5. Livestock trails on a slope. In the foreground large bushes of *Phlomis thapsoides*.

Fig. 6. Livestock trails on slopes.

Phlomis thapsoides is a large, perennial plant which is bitter and therefore not consumed by livestock while green, so it persists all summer, creating an original view of the landscape (Fig. 5). After drying it loses its bitter taste and can then be eaten by all types of livestock. In drought years, when there is not enough fodder and straw from wheat, local people prepare *Phlomis thapsoides* as winter forage.

In arid climatic conditions exposure plays an important role in the distribution of heat and moisture. In otherwise identical conditions (elevation, steepness of slope, etc.), large differences in temperature were observed between northern and southern slopes in air between 12.00 and 17.00h, and at the soil surface between 09.00 and 18.00h. Maximum temperature differences reached 2.2°C in air and 8.6°C at the soil surface (Rakhmatullaev, 2010). On slopes with north, northwest and northeast exposures vegetation is richer both in species composition and in certain plant species.

Up to now there has been no clarity in the scientific literature on the terminology of desertification. Due to the absence of precise criteria, desertification is often described as any deterioration of natural conditions of a given area. On the basis of an analysis of several studies devoted to the processes of desertification we have come to the conclusion that the exhaustion of at least 50% of the natural resources in a geosystem (onosystem) should be considered as the beginning of the process of desertification. This represents a breaking point beyond which the natural circulation of nutrients and energy in geosystems is strongly broken. If more than 50% of natural resources are lost nature can recover only very slowly and several decades are required to return to the previous state.

The question then arises: why take the initial point of desertification as 50%, rather than 40 or even 30%? These values also represent substantial levels of deterioration, but 50% - i.e. half – is a breaking point. Transition beyond 50% results in a disruption of balance and, at the expense of easing natural processes, new artificial processes linked to anthropogenic pressure amplify. According to sinenergy, 50% is also a critical point (Prigojin and Stengers 1986).

Conclusions

As the human population grows, the anthropogenic load on nature increases not only in oases, but also in mountain systems. Around settlements, the load on rangelands exceeds their capacity ten times, therefore the natural condition of mountains worsens from year to year: soil erosion increases, springs and streams dry up, mudflow events become frequent.

To measure desertification processes we organized an experimental site in the eastern part of Gobduntau mountain range near Ishmantup settlement, where the influence of economic activity of the people on rangelands is studied. Results have shown that within a radius of 2 km around settlements rangeland productivity is reduced by 40 - 100%. The influence of grazing decreases gradually with increasing distance from settlement.

In Central Asia, we consider the beginning point of desertification to be a 50% reduction in the productivity of rangelands. According to this criteria, we have begun drawing up a map of desertification of separate sites as well as the whole Gobduntau mountain range. Soil erosion, drying up of springs and streams etc. can be considered as additional parameters. Results of this work will be presented in a future article.

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